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International Journal of Psychophysiology 117 (2017) 37–47

Date of Publication from Ext Publisher: April 2017

Defence Research and Development Canada
External Literature (P)
DRDC-RDDC-2017-P076
September 2017

IMPORTANT INFORMATIVE STATEMENTS

Template in use: (2012) CR EL1 Advanced Template_EN 2017-09_21-V02_WW.dotm

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Keywords:
Military
Cortisol
Dissociation
Fatigue
Anxiety
Working memory

A B S T R A C T

In the Canadian Armed Forces (CAF), Conduct After Capture (CAC) training is a 4-day captivity survival course during which soldiers are exposed to increasing stress, and evaluated on their ability to accomplish military objectives. We hypothesized that: (a) compared to baseline, CAC training would cause significant, reversible perturbations in measures of psychological functioning and serum and salivary stress hormone levels relevant to models of stress hardiness and vulnerability; and (b) deviations from baseline would be maximal at the time point of most intense stress during training. CAF personnel were assessed at baseline, twice during training (immediately prior to a less challenging interrogation role-play scenario and again following another much more intense interrogation role-play scenario), and after completion of training. At each occasion, mood, fatigue, dissociation, PTSD symptoms, short-term and working memory, and salivary cortisol and dehydroepiandrosterone (DHEA) were assessed. As predicted, scores on all measures were degraded during CAC but recovered after completion of training, and almost all measures were most degraded at the more intense interrogation role-play scenario. Unexpectedly, memory performance was unaffected by training, suggesting that a short duration of intense stress might be insufficient for degrading it. Another unexpected finding was that mood assessed prior to training predicted successful completion of training, which bears important practical implications for increasing the success rate of training in similar environments. These results demonstrate that despite its relative brevity, CAC training nevertheless induces significant but reversible effects on psychological and physiological function—necessary preconditions for stress inoculation training.

1. Introduction

Combat operations induce stress due to sleep deprivation, fatigue, hunger, dehydration, physical discomfort from adverse climatic conditions and physical fatigue. Such stressors compromise psychological and physical function (Lieberman et al., 2005a), with potentially serious consequences for soldiers' performance. Therefore, it is important to prepare soldiers by providing skills to preserve optimal performance under such stressful conditions. According to stress inoculation theory (Meichenbaum, 1985), enhanced resilience to stress can be developed by training. Specifically, coping mechanisms for mitigating the effects of combat-related stress on performance can be taught using controlled exposure to operationally realistic stressors during training (Stetz et al., 2007). According to this model, training must be designed such that it can expose trainees to stress levels sufficient to activate their psychological and biological coping mechanisms, but not to stress them so greatly so as to overwhelm them beyond the possibility of recovery.

In the Canadian Armed Forces (CAF), Conduct After Capture (CAC) training represents a 4-day captivity survival course during which soldiers are exposed to increasing levels of stress, including acute uncontrollable stress, and evaluated on their ability to accomplish

Acronyms: ACTH, adrenocorticotropic hormone; BTQ, Brief Trauma Questionnaire; CTQ, Childhood Trauma Questionnaire; CAC, Conduct After Capture; CADSS, Clinician-Administered Dissociative States Scale; CAF, Canadian Armed Forces; DHEA, dehydroepiandrosterone; dMTS, Delayed Matching-to-Sample; HPA, hypothalamus-pituitary-adrenal; MFI, Multidimensional Fatigue Inventory; NPY, neuropeptide Y; POMS, Profile of Mood States; PSS, PTSD Symptom Scale; PTSD, post-traumatic stress disorder; SERE, Survival, Evasion, Resistance, and Escape; SNS, sympathetic nervous system; WM, working memory

military objectives such as protecting operationally sensitive information as required by CAF policy (Department of National Defence, 2004). The course objective is to train soldiers on the skills necessary for captivity survival under conditions of high levels of fidelity and realism. Ideally, CAC training will induce sufficiently high levels of transient controlled stress to facilitate inoculation, following which a return to baseline will occur. However, to date, the effects of training-related stress on psychological and physiological function in CAC training have not been quantified.

The basic structure of CAC training resembles some core features of the U.S. military's captivity survival training course—termed *Survival, Evasion, Resistance, and Escape* (*SERE*). Three features of the SERE course make it ideal for studying the effects of acute, uncontrollable stress on psychological and physiological function. First, participants are selected from populations that could potentially find themselves in captivity. Second, course design and scheduling ensure a uniform application of stress across all participants. Finally, because the nature of the stress is highly realistic and intense, the effects of stress on human function can be studied with high external validity. A large body of data exists that characterizes the effects of SERE training on both the psychological performance and neurobiological responses of participants to stress (Lieberman et al., 2005a; Morgan et al., 2006; Morgan et al., 2000a-b; Morgan et al., 2001a-b; Morgan et al., 2009; Lieberman et al., 2015; Lieberman et al., 2016; Taylor et al., 2007). Because key features of CAC training are modeled on U.S. SERE training, the findings from U.S. SERE studies can form the basis for generating predictions about possible effects of CAC training on psychological and physiological function. Critically, however, whereas the duration of the SERE course is three weeks, the duration of CAC training is only four days (United States Navy and Marine Corps, 2013). As such, despite similarities in basic structure, it is unknown whether the psychological and physiological perturbations observed in the context of SERE training will be observed in the context of CAC training.

Previous SERE studies have demonstrated that such training is associated with significant perturbations in both psychological and physiological function. In terms of the former, acute stress induced by captivity survival training has been shown to impair episodic and working memory and visuospatial and problem solving abilities (Lieberman et al., 2005a; Morgan et al., 2006; Morgan et al., 2000a-b; Morgan et al., 2001a-b). In addition, exposure to SERE training stress was associated with significantly greater self-reported dissociation, distortions in sensory perception, and in an increase in endorsed PTSD-like symptoms (Morgan et al., 2001b). Military studies evaluating soldiers undergoing significant, extended stress during U.S. Army Ranger training exercises, or during the “Hell Week” of U.S. Navy SEAL training, have provided evidence of similar stress-induced degradation in cognition, perturbation of mood and increased fatigue as observed in soldiers exposed to the acute stress of SERE training (Lieberman et al., 2005a; Lieberman et al., 2009).

The effects of captivity survival training on hormone levels are also well documented. The stress of training results in elevations in cortisol, and three other well established biomarkers of stress, dehydroepiandrosterone (DHEA), neuropeptide Y (NPY), and epinephrine (EPI) (Morgan et al., 2000a-b; Morgan et al., 2001a; Lieberman et al., 2016). Each of these represents the activity of separate functional systems (Morgan et al., 2000a), so stress-induced alterations in these physiological systems are consistent with the idea that SERE represents a valid ethological model for the study of acute stress in humans. These physiological biomarkers of stress were affected by captivity survival training in U.S. SERE schools to a degree that was equal to or greater than alterations measured in individuals undergoing major surgery or actual combat (Morgan et al., 2000a,b).

Certain patterns of hormone secretion in response to stress have been associated with effective coping with stress. For example, an effective stress response may be associated with rapid elevation of certain stress hormones, such as NPY, in response to acute stress, followed by a return to baseline following the termination of the acute stress (Morgan et al., 2000a). This response profile can be used to assess how well individuals are coping with transient, intense stressors. Ideally, for the purposes of stress inoculation, i.e., a situation in which realistic exposure to stress is expected to confer an enhanced ability to tolerate future stress, CAC training should induce a measurable increase in acute stress that will return to (near) pre-training levels shortly following termination of the course (Meichenbaum, 1985; Stetz et al., 2007).

The objective of the present study was to quantify the effects of CAC training on specific aspects of psychological functioning and on specific neurohormones known to be related to stress responding. Data were collected at the following time points in training: at baseline (the Didactic Phase of training); twice during simulated captivity (the Practical Phase); and finally at the Recovery/Debriefing Phase. Measures of psychological function consisted of measures of mood, fatigue, dissociation, PTSD symptoms, short-term memory and working memory (WM). Measures of salivary physiological function consisted of cortisol and DHEA. Cortisol is considered to be one of the best biological markers of stress. DHEA is a major secretory product of the adrenal glands, and is co-released with cortisol in response to adrenocorticotropic hormone (ACTH) release from the pituitary gland. DHEA is associated with immune function, and within the nervous system acts as a neuroactive and neuroprotective factor (Salimetrics, 2011). We also collected blood samples, but only at baseline and the Recovery/Debriefing Phase so as not to interfere with CAC training. This enabled us to assess whether serum biomarkers of stress would exhibit sensitivity to the effects of CAC training. However, our analyses based on serum biomarkers must be considered exploratory because collecting data only before and after training does not allow one to make direct inferences about the effects of stress experienced during training.

1.1. Predictions

Based on results of similar studies conducted in the U.S (Lieberman et al., 2005a; Morgan et al., 2006; Morgan et al., 2000a-b; Morgan et al., 2001a-b; Lieberman et al., 2015; Lieberman et al., 2016; Taylor et al., 2007), our first prediction was that, compared to baseline, CAC training would cause significant, reversible perturbations in measures of psychological functioning and in specific stress hormone levels known to be relevant to models of stress hardiness and vulnerability. Specifically, consistent with previous scientific research at SERE, our first prediction was that CAC training would, compared to baseline levels of performance: (1) impair cognitive functioning as measured by the delayed Matching-to-Sample (dMTS) and N-back tests, (2) disrupt mood as measured by the Profile of Mood States (POMS), (3) increase fatigue as measured by the Multidimensional Fatigue Inventory (MFI), (4) increase dissociation as measured by the Clinician-Administered Dissociative States Scale, (5) increase PTSD symptoms as measured by the PTSD Symptom Scale, and (6) increase cortisol and DHEA levels. We also predicted that levels of cognitive functioning, mood and hormones would return to pre-stress, baseline levels at the conclusion of the training. Our second prediction was that deviations from baseline in all the aforementioned measures would be maximal at the time point of most intense stress during training (i.e., second interrogation role-play scenario).

In addition, the blood samples collected at baseline and the Recovery/Debriefing Phase were used to measure cortisol, DHEA, testosterone, NPY and lactate—all of which are recognized biomarkers of stress. Our third prediction was that compared to baseline, at the Recovery/Debriefing Phase we would observe increases in serum levels of cortisol, DHEA, NPY and lactate, but reductions in testosterone. This pattern involving serum biomarkers would be consistent with the observation that post-training stress levels would be higher compared to baseline.

Table 1
Assessment protocol.

CAC training phases		
Didactic phase Instruments	Practical phase	Recovery/debriefing phase
- Consent process	- First practical assessment (Time 2/T2)	- Recovery/debriefing (Time 4/T4)
- Eligibility screening	Dissociation	Dissociation
- Baseline(Time 1/T1)	Mood/PTSD	Mood/PTSD
Dissociation	Cognitive function	Cognitive function
Mood/PTSD	Saliva sampling	Body weight
Cognitive function	- Second practical assessment (Time 3/T3)	Saliva sampling
Body weight	Dissociation	Blood sampling
Saliva sampling	Mood/PTSD symptoms	Actigraph removal
Blood sampling	Cognitive function	
Actigraph installment	Saliva sampling	

2. Material and methods

2.1. General overview

CAC training is conducted over 4 days, and has three phases; Didactic, Practical, and Recovery/Debriefing (Table 1). The Didactic Phase is the academic portion of training, and consists of long hours of lectures as well as role-playing practice sessions. During the Practical Phase students undergo a highly realistic simulated captivity experience. This simulation consists of exposing each student to increasing levels of stress, including acute uncontrollable stress, in the course of which they are required to avoid exploitation by their mock captors. The Practical Phase replicates some known techniques of enemy captors and includes mock interrogations and problem solving dilemmas designed to test students' ability to adhere to the *Canadian Forces Code of Conduct After Capture* (Department of National Defence, 2004). Finally, during the Recovery/Debriefing Phase students are provided feedback on their performance and given an opportunity to ask the instructors any question they might have.

The present study was designed to allow the experimenters to collect data during CAC training without interfering with its conduct. All participants travelled approximately 3 h by bus in the early hours of the morning of the first day of training to arrive at the training location. Upon arrival they immediately started the Didactic Phase, were briefed about the study by CAC staff and had questions about participation in this study answered by the experimenters. They were then given the opportunity to volunteer by reading and signing informed consent forms. Baseline assessments (see Procedures) were conducted following the collection of written informed consent, and immediately prior to commencement of didactic lectures. Participants had approximately 6 h of sleep during the Didactic Phase of training. In the Practical Phase, all participants were subjected to the same level of severe sleep deprivation. They were also subject to food restriction/deprivation throughout training. During the Practical Phase they received water on a prescribed schedule, and were continuously monitored by medical staff. The first experimental assessment during the Practical Phase occurred after a period of both food and sleep deprivation and immediately prior to the first training event, an interrogation and role-playing scenario, and included relevant psychological and hormonal measures (see Procedures). Then, following approximately 24 h of food and sleep deprivation, participants were exposed to a more challenging training event, an intense interrogation and role-playing scenario. The second assessment during the Practical Phase occurred immediately after this training event and included the relevant psychological and hormonal measures (see Procedures). The Recovery/Debriefing Phase began approximately 2–4 h after the completion of training, at which point psychological and hormonal measures were collected from all volunteers who completed training (see Procedures).

In terms of food, during the Didactic Phase (Table 1) participants received military boxed lunches (with the exception of one meal). Typically, military boxed lunches consist of a sandwich or a bagel, and either a fruit or vegetables as the snack. Any high calorie snack or drink (e.g., cookies or apple juice) was removed. No food was provided during the Practical Phase of training (Table 1). Water was provided ad libitum during the Didactic Phase. In turn, during the Practical Phase, participants received 250 ml of water every 4–6 h. At the Debriefing/Recovery Phase (Table 1), the Medical Oversight provided the participants with information on how to slowly reintroduce food, and how to rehydrate properly.

2.2. Participants

Participants were thirty-six (35 males, 1 female; age range 23–45 years) CAF military personnel undergoing CAC training. All were medically and psychologically screened prior to commencing training. Ethical approval for the study was granted by Human Research Ethics Committee of Defence Research and Development Canada. All participants provided written informed consent prior to taking part in the study, and understood that involvement in the study would have no impact on their training status. The majority of participants were non-commissioned Regular Force members (89%), having between 6 and 15 years of military service (78%).

Ninety-five percent of the participants had had at least one deployment in the previous five years, and 68% had been exposed to combat. Fifty-seven percent had engaged the enemy and 75% indicated that they had at some point felt that they were in immediate danger of death or injury. Of the 36 participants who volunteered for the study, 28 completed all aspects of the training (27 males, 1 female). Failure to complete the training was due to medical removal (n = 4), training failure (n = 1), and voluntary withdrawal (n = 3).

2.3. Materials

2.3.1. The Brief Trauma Questionnaire (BTQ)

The BTQ (Schnurr et al., 1999) is a 10-item self-report instrument that assesses history of exposure to potentially traumatic events such as natural disaster, childhood physical abuse, muggings, and assault. Individuals who have experienced a potentially traumatic event are asked two additional questions: “Did you fear for your life?” and “Were you seriously injured physically?” The additional questions are designed to ascertain whether or not the potentially traumatic event meets the DSM-IV criteria for a “traumatic event.” The BTQ score reflects the total number and types of trauma experiences as well as whether the DSM-IV criteria for traumatic stress exposure were met. The BTQ was administered once at baseline.

2.3.2. The Childhood Trauma Questionnaire (CTQ)

The CTQ (Bernstein and Fink, 1998) is a 28-item self-report instrument that screens for history of abuse and neglect. The five subscales include physical, emotional and sexual abuse as well as physical and emotional neglect. The CTQ includes a 3-item minimization/denial scale to detect socially desirable responses. Research suggests exposure to childhood trauma influences HPA axis reactivity and thus may influence stress resilience. The CTQ was administered once at baseline.

2.3.3. Clinician-Administered Dissociative States Scale (CADSS)

This 19-item self-report scale is designed to measure how aware an individual is of their environment (Bremner et al., 1998). Sample items include “Do you feel as if you are looking at things outside of your body?” and “Do colours seem to be diminished in intensity?” The CADDS was administered at baseline, twice during training, and finally

at Recovery/Debriefing.

2.3.4. PTSD Symptom Scale (PSS)

The PSS (Foa et al., 1993) is a 17-item self-report measure of PTSD symptoms. The items measure how often specific states (e.g., being overly alert, feeling irritable or having fits of anger) occurred in the respondent. This measure is a conservative indicator of PTSD according to the DSM-III-R criteria. When summed, PSS results can be divided into 5 categories (below threshold, subclinical-mild, mild, moderate, and severe). The PSS was administered at baseline, twice during training, and finally at Recovery/Debriefing.

2.3.5. Multidimensional Fatigue Inventory (MFI)

The MFI (Smets et al., 1995) is a 20-item self-report instrument designed to measure general, physical, mental, motivation and activity aspects of fatigue. The MFI was administered at baseline, twice during training, and finally at Recovery/Debriefing.

2.3.6. Profile of Mood States (POMS)

The POMS (McNair et al., 1971) assesses six dimensions of mood state: depression/dejection, vigor/activity, anger/irritability, fatigue, confusion/bewilderment and anxiety/tension. Values on the five negative mood states are summed together and the vigor score is subtracted to provide a Total Mood Disturbance score. The POMS has been validated in generally healthy persons as well as those suffering from anxiety or mood disorders. It was administered at baseline, twice during training, and finally at Recovery/Debriefing.

2.3.7. Delayed Matching-to-Sample (dMTS)

The dMTS (Miller et al., 1996) is a classic measure of short-term memory from the animal learning and WM literatures. It is sensitive to effects of acute stress and fatigue (Shurtleff et al., 1994; Lieberman et al., 2002; Mahoney et al., 2007). Each dMTS trial involves the encoding, maintenance, and retrieval of stimulus representations in sequential order. Specifically, during *encoding* participants memorize the stimulus (i.e., in the form of an 8×8 grid of green and red squares), during *retention* they maintain the stimulus in visual short-term memory, and during *retrieval* they press the button corresponding to one of the two stimuli that matches the stimulus presented during *encoding*. The delay between presentations of the initial stimuli and presentation of the matching choice varied from 1 to 3 s. The dMTS was administered at baseline, twice during training, and finally at Recovery/Debriefing. Accuracy and reaction time (RT) were recorded.

2.3.8. N-back

This task is used to assess WM, defined as "a multicomponent system for active maintenance of information in the face of ongoing processing and/or distraction" (Conway et al., 2005). The n-back requires that participants decide, on a trial-by-trial basis, whether a stimulus (i.e., letter) presented in the current trial matches a target stimulus presented a specific number of trials earlier in the sequence. The letter n denotes the specific number of trials that separate the current trial from the target trial. This task requires maintenance and updating of dynamic rehearsal sets (Kane et al., 2007). In this study n was either 1 to 2. The n-back was administered at baseline, twice during the Practical Phase, and finally at Recovery/Debriefing. Accuracy was automatically recorded.

2.4. Procedures

Table 1 lists measures collected at baseline immediately prior to commencement of the Didactic Phase. The measures included paper-and-pencil administration of the BTQ, CTQ, PSS, CADSS, and MFI. In addition, all participants completed a computerized task battery that included the POMS and assessed dMTS and n-back performance (Beatty et al., 2015). Body weight was also assessed.

We were able to quantify sleep, rest and activity periods based on the analysis of the actigraphic data. At baseline, each participant was equipped with a wrist actigraph (Ambulatory Monitoring, Inc., Ardsley, NY) worn on the non-preferred hand to reduce interference with use of the dominant hand. Actigraphs have been widely employed in civilian and military laboratories to assess patterns of rest and activity, sleep and energy expenditure in laboratory and field studies (Sadeh et al., 1994). Validated algorithms (Lamond and Dawson, 1999) were used to determine the extent and quality of sleep.

Saliva samples were obtained from all participants at three time points (morning, afternoon, evening) on Day 1 of training, to control for diurnal variation in patterns of adrenal hormone release (for comparison to later measurements). Prior to salivary sample collection, all participants abstained from eating or drinking any beverage except for water, smoking or use of smokeless tobacco. Saliva was collected using Salivette Cortisol tubes (SARSTEDT Inc., Montreal, QC). After collection the Salivette was immediately centrifuged at 2700g for 5 min to yield clear saliva, and the samples were frozen and stored at $-70\,^{\circ}C$ until analyses. Immediately prior to analysis, frozen samples were thawed at room temperature, vortexed and centrifuged at 1500g for 15 min. The samples were analyzed for cortisol and DHEA with enzyme immunoassay kits (Salimetrics, LLC, State College, PA) as per manufacturer's instructions.

Consent to donate blood was obtained separately to enable participants to opt out of donating blood if they desired. For a subset of participants ($n = 24$) who consented to donate blood, samples were collected at baseline. There was no relationship (assessed using Chi-Square) between consenting to give blood and any of the key demographic data including (a) rank, (b) marital status, (c) highest level of education, (d) prior exposure to combat, (e) prior engagement with enemy, or (f) having been in immediate danger of death or injury (all $p > 0.05$).

Blood samples were analyzed in two steps, using two different methods. In the first instance blood samples were analyzed using immunoassay kits per manufacturer's instructions for lactate (Abnova, Taipei City, Taiwan), NPY (Abnova, Taipei City, Taiwan), and DHEA (Alpco, Salem, NH). Approximately one year later, the remaining portions of the same samples were analyzed for testosterone and cortisol using mass spectrometry. In the latter case LTQ XL Orbitrap Discovery was used in ion-trap mode to conduct selected reaction monitoring (SRM) experiments. SRM is a method used in mass spectrometry where a predefined precursor ion and one of its fragments are selected by mass filters and monitored over time for precise quantification (Lange et al., 2008) to monitor testosterone and cortisol levels. Finally, each participant was weighed using a calibrated scale so changes in body mass that occurred as a result of training could be determined.

The first assessment during the Practical Phase took place after approximately 12 h of captivity and was conducted immediately prior to the first mock-interrogation and the second, after approximately 24 h of simulated captivity, and immediately following an intense interrogation and role-playing scenario. The two assessment sessions conducted during the Practical Phase included the PSS, CADSS, MFI, POMS, dMTS and n-back (Table 1). Salivary samples were also collected at those times. Finally, the Recovery/Debriefing Phase assessment occurred 2–4 h after the completion of the Practical Phase and included administration of the PSS, CADSS, MFI, POMS, dMTS, and the n-back. Saliva and blood samples were also collected at this time and body weight was assessed.

3. Results

3.1. Data integrity

Missing data were treated using listwise deletion at the item level. Data loss was generally low and ranged from 0 to 4% on all measures

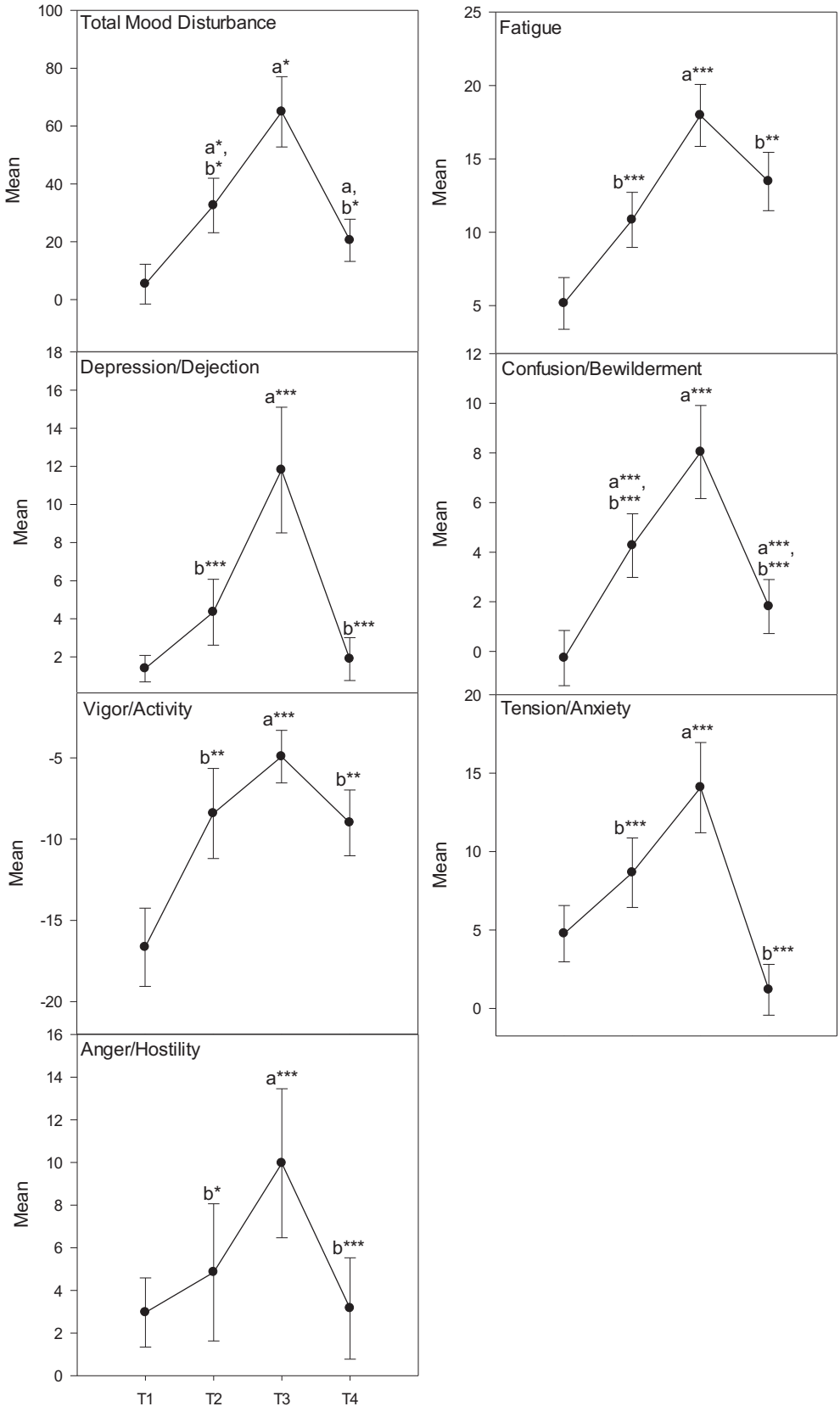

Fig. 1. Effect of CAC training on Profile of Mood States.Notes: [a] = significant difference from T1; [b] = significant difference from T3; Significance levels: (*) = $p \leq 0.05$, (**) = $p \leq 0.01$, (***) = $p \leq 0.001$. Error bars indicate 95% confidence intervals.

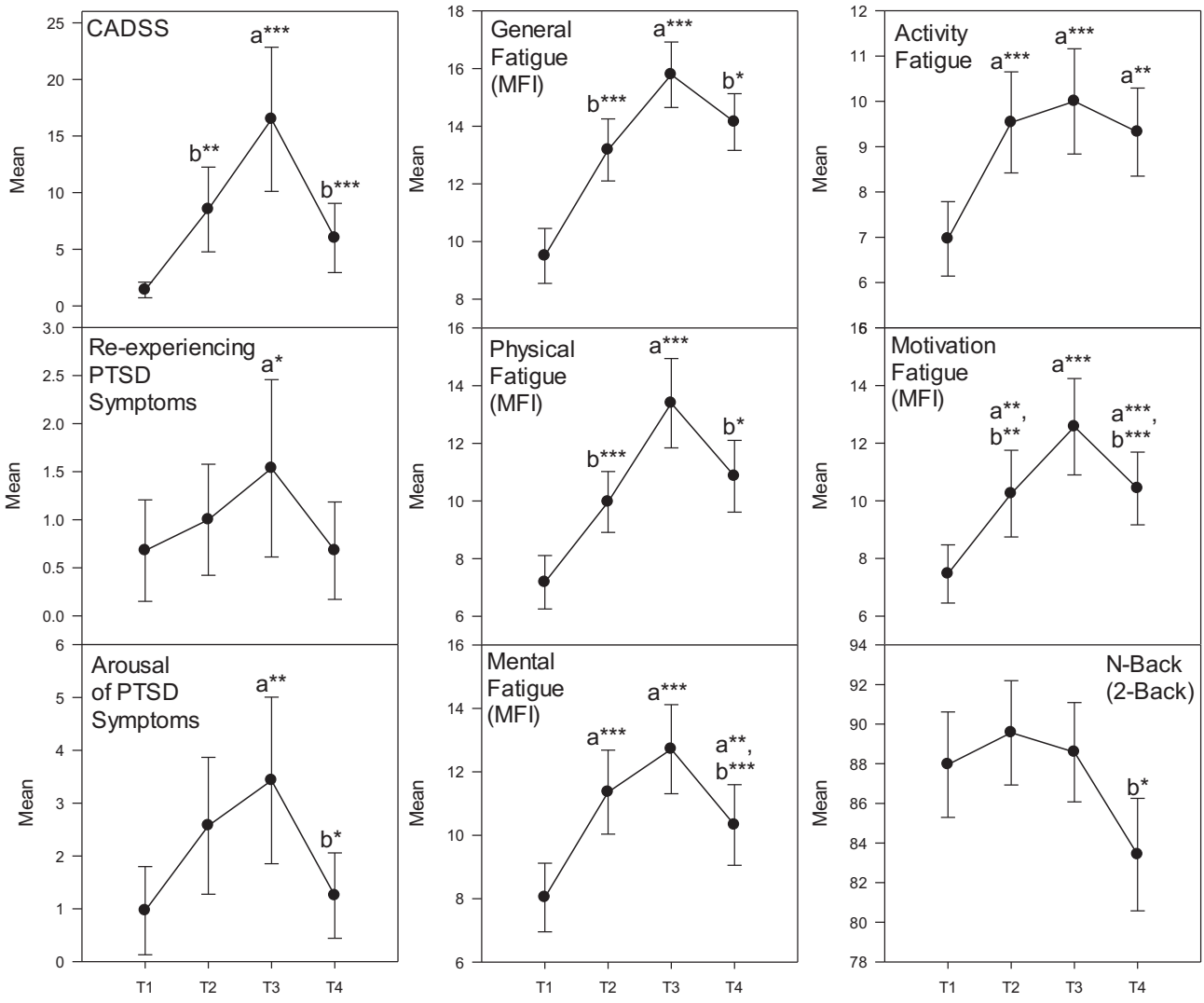

Fig. 2. Effect of CAC training on Clinician-Administered Dissociative States Scale, Multidimensional Fatigue Inventory, and N-Back (2-back) test.Notes: [a] = significant difference from T1; [b] = significant difference from T3; Significance levels: (*) = $p \leq 0.05$, (**) = $p \leq 0.01$, (***) = $p \leq 0.001$. Error bars indicate 95% confidence intervals.

except blood, for which data loss was higher (range 14–18%).

3.2. Manipulation check

During practical training participants are deprived of food and sleep (see Materials and methods). To determine whether these manipulations were successful, we examined whether food and sleep deprivation had demonstrable effects on volunteer body weight and sleep duration. For weight, we conducted a paired-samples *t*-test based on measurements taken at baseline and Recovery/Debriefing Phases. Participants lost an average of 3.6% (SD = 0.07, range: 2.2–5%) of their body weight over the 4-day period of training, $t(27) = 28.49$, $p < 0.001$. For sleep, the actigraphic data demonstrated that on average the first night's sleep had a duration of 5 h and 36 min (SD = 24 min). In turn, during the Practical Phase of training, the average sleep period had a duration of 1 h and 45 min (SD = 23 min). The latter is an indication that during the Practical Phase of training the participants had less sleep than would be expected to occur under normal circumstances.

3.3. History of trauma

Frequency data were tabulated and scored according to type of trauma exposure and whether DSM-IV criteria were met for traumatic stress exposure. Based on responses to the BTQ, 13 participants met the criteria for traumatic stress exposure based on fearing for their lives, and four met the criteria for traumatic stress exposure based on having been seriously injured. Based on their responses to the CTQ, two participants endorsed low levels of emotional abuse, five participants reported low-to-moderate levels of physical abuse, one participant reported severe sexual abuse, and all participants reported some degree of emotional neglect—15 low, 19 moderate, and 2 severe. Physical neglect was endorsed by six participants (three low, two moderate, one severe). Based on the endorsement of denial items, eleven participants may have been minimizing their experiences of childhood trauma.

3.4. Completers and non-completers of training

There were significant differences between those who completed (78%) and those who did not complete training on specific psychological measures at baseline. Completers of the course had lower scores than non-completers on 2 subscales of the POMS, Confusion/Bewilderment ($t(34) = 2.22$, $p < 0.04$, $d = 0.89$) and Depression/Dejection ($t(34) = 2.41$, $p < 0.03$, $d = 0.97$), and higher scores on the Vigor/Activity sub-scale ($t(34) = 2.45$, $p < 0.03$, $d = 1.87$). There were no significant differences between the two groups on the other subscales of the POMS and Total Mood Disturbance, traumatic stress exposure, Childhood Trauma, Dissociation symptoms, PSS symptoms, and any subscale of the MFI.

In addition, there were no significant differences between completers and non-completers on: weight; salivary cortisol; salivary DHEA; salivary cortisol/DHEA ratio; blood cortisol; blood testosterone; blood lactate; blood NPY; and blood DHEA.

3.5. Effects of training on outcome measures

Unless stated otherwise, we assessed the effect of CAC training on outcome measures using repeated-measures, within-subjects ANOVAs. Specifically, we assessed whether exposure to CAC training was associated with variations in psychological function and hormone levels across the following four assessment time points: Baseline (Time 1: T1), first practical assessment (Time 2: T2), second practical assessment (Time 3: T3), and Recovery/Debriefing (Time 4: T4). This four-level variable will be referred to as time. We hypothesized that T3—the time point immediately following the more challenging interrogation role-play scenario—would be associated with the greatest level of stress compared to the other three time points. All reported results were corrected by the Greenhouse-Geisser procedure where appropriate. Bonferroni adjustments were applied to all post-hoc analyses.

3.5.1. Mood

For Total Mood Disturbance, there was a significant effect for time, $F(3, 75) = 59.00$, $p < 01$, partial $\eta^2 = 0.70$ (Fig. 1). For the subscales of the POMS, there was a significant effect of time on the degree of depression/dejection, $F(1.65, 41.25) = 30.22$, $p < 0.01$, partial $\eta^2 = 0.55$ (Fig. 1). For the vigor/activity subscale, the there was a significant effect of time, $F(3, 75) = 33.15$, $p < 0.01$, partial $\eta^2 = 0.57$ (Fig. 1). For the anger/hostility subscale, there was a significant effect for time, $F(1.88, 47.00) = 15.13$, $p < 0.01$, partial $\eta^2 = 0.38$ (Fig. 1). For the fatigue subscale there was a significant effect of time, $F(3, 75) = 45.05$, $p < 0.01$, partial $\eta^2 = 0.64$ (Fig. 1). For the confusion/bewilderment subscale, there was also a significant effect of time, $F(2.04, 50.87) = 44.57$, $p < 0.01$, partial $\eta^2 = 0.64$ (Fig. 1). For the tension/anxiety subscale, there was a significant effect of time, $F(3, 75) = 44.81$, $p < 0.01$, partial $\eta^2 = 0.64$ (Fig. 1).

3.5.2. Dissociation

There was a significant effect of time on dissociation, $F(1.59, 41.25) = 20.27$, $p < 0.01$, partial $\eta^2 = 0.44$ (Fig. 2).

3.5.3. PTSD

There was no significant effect of time on overall symptoms reported and the avoidance subscale ($p > 0.05$). However, over the course of CAC training there were significant increases in the re-experiencing subscale of the PSS, $F(1.93, 51.96) = 4.05$, $p < 0.05$, partial $\eta^2 = 0.13$ (Fig. 2). Similarly, CAC training had a significant effect on the degree of arousal, $F(2.29, 61.70) = 7.69$, $p < 0.001$, partial $\eta^2 = 0.22$ (Fig. 2).

3.5.4. Fatigue

CAC training had a significant effect on all MFI subscales. There was a significant effect of time on general fatigue, $F(3, 81) = 39.87$, $p < 0.001$, partial $\eta^2 = 0.60$ (Fig. 2). Time also had a significant effect on physical fatigue, $F(1.98, 53.36) = 28.13$, $p < 0.001$, partial $\eta^2 = 0.51$ (Fig. 2). Time had a significant effect on mental fatigue, $F(3, 81) = 18.89$, $p < 0.001$, partial $\eta^2 = 0.41$ (Fig. 2). Time had a significant effect on activity fatigue, $F(3, 81) = 51.58$, $p < 0.001$, partial $\eta^2 = 0.33$ (Fig. 2). Finally, time had a significant effect on motivation fatigue, $F(3, 81) = 16.56$, $p < 0.001$, partial $\eta^2 = 0.38$ (Fig. 2).

3.5.5. Cognitive performance

For the dMTS task, CAC training did not have a significant effect on overall percent accuracy ($p > 0.05$). The n-back task included two levels of *n*: 1-back (relatively easier) and 2-back (relatively more difficult). CAC training had no significant effect on accuracy on 1-back ($p > 0.05$). In contrast, CAC training did affect performance on 2-back, $F(3, 75) = 6.38$, $p = 0.001$, partial $\eta^2 = 0.20$ (Fig. 2).

3.5.6. Saliva cortisol and DHEA

Because measurements of salivary cortisol and DHEA were obtained at multiple time points throughout the study, an analytic procedure was implemented in order not to violate the independence assumption when computing a correlation coefficient (Bland, 2000). Specifically, for each participant, we first computed average cortisol and DHEA scores across all time points. In turn, correlations were computed involving those averaged data points. As expected, there was a positive correlation between salivary cortisol and DHEA levels, although the correlation coefficient did not reach statistical significance, $r(26) = 0.34$, $p < 0.076$.

Typically, more cortisol is released in the morning than in the afternoon or evening (Weitzman et al., 1971). This diurnal pattern of salivary cortisol release was examined by evaluating cortisol in the morning, afternoon and evening of Day 1. The observed pattern was as expected and a repeated-measures ANOVA demonstrated time of day (morning, afternoon, evening) had a significant effect on levels of salivary cortisol (measured in μg/dl), $F(2, 68) = 36.52$, $p < 0.001$, partial $\eta^2 = 0.52$. Post hoc tests by within-subjects contrasts demonstrated cortisol levels decreased linearly from the morning to the evening, $F(1, 34) = 58.75$, $p < 0.001$, partial $\eta^2 = 0.63$. Time also had a significant effect on salivary cortisol, $F(2.189, 59.09) = 54.370$, $p < 0.001$, partial $\eta^2 = 0.67$ (Fig. 3).

A repeated-measures ANOVA demonstrated time of day (morning, afternoon, evening) also had a significant effect on levels of salivary DHEA (measured in μg/dl), $F(2, 70) = 10.45$, $p < 0.001$, partial $\eta^2 = 0.23$. However, the observed pattern did not reflect our prediction. Specifically, within-subjects contrasts demonstrated that DHEA levels exhibited a quadratic effect, peaking in the afternoon compared to morning and evening levels, $F(1, 35) = 18.92$, $p < 0.001$, partial $\eta^2 = 0.35$. Like cortisol, salivary DHEA levels were also significantly affected by time, $F(1.6, 42.31) = 16.54$, $p < 0.001$, partial $\eta^2 = 0.38$ (Fig. 3). The ratio of salivary DHEA to cortisol was not significantly affected by time, $F(3, 72) = 2.05$, n/s.

3.5.7. Blood lactate, testosterone, cortisol, DHEA and NPY

Since blood was only collected on two occasions, we employed paired-samples *t*-tests to compare differences in blood testosterone, cortisol, lactate, DHEA and NPY levels between the baseline and Recovery/Debriefing Phases. Compared to baseline, testosterone levels were lower in the Recovery/Debriefing Phase, $t(23) = 6.44$, $p < 0.001$, $d = 1.45$ (Fig. 3). Compared to baseline, DHEA levels were also lower in the Recovery/Debriefing Phase, $t(22) = 5.42$, $p < 0.001$, $d = 0.97$ (Fig. 3). Similarly, compared to baseline, cortisol levels were lower in the Recovery/Debriefing Phase, $t(23) = 3.03$, $p < 0.01$, $d = 1.40$ (Fig. 3). In contrast, relative to baseline, lactate levels were higher in the Recovery/Debriefing Phase, $t(22) = -2.79$, $p < 0.05$, $d = 0.82$ (Fig. 3). There was no change in NPY levels between the baseline and Recovery/Debriefing Phases, $t(22) = -1.38$, n/s, $d = 0.70$ (Fig. 3).

3.5.8. History of trauma and stress reactivity

Prior research on healthy military members in the context of captivity survival training suggests that prior trauma influences peritraumatic dissociative responses (Morgan et al., 2001b), cognitive impairment (Morgan et al., 2006), and poststress health symptoms (Dimoulas et al., 2007). To examine whether history of trauma might have affected how participants responded to stress in the present context, we focused on the BTQ because responding in the affirmative to either one of two questions (i.e., “Did you fear for your life?” or “Were you seriously injured physically?”) is interpreted as fulfilling *DSM-IV* (*Diagnostic and Statistical Manual of Mental Disorders*, 4th ed.)

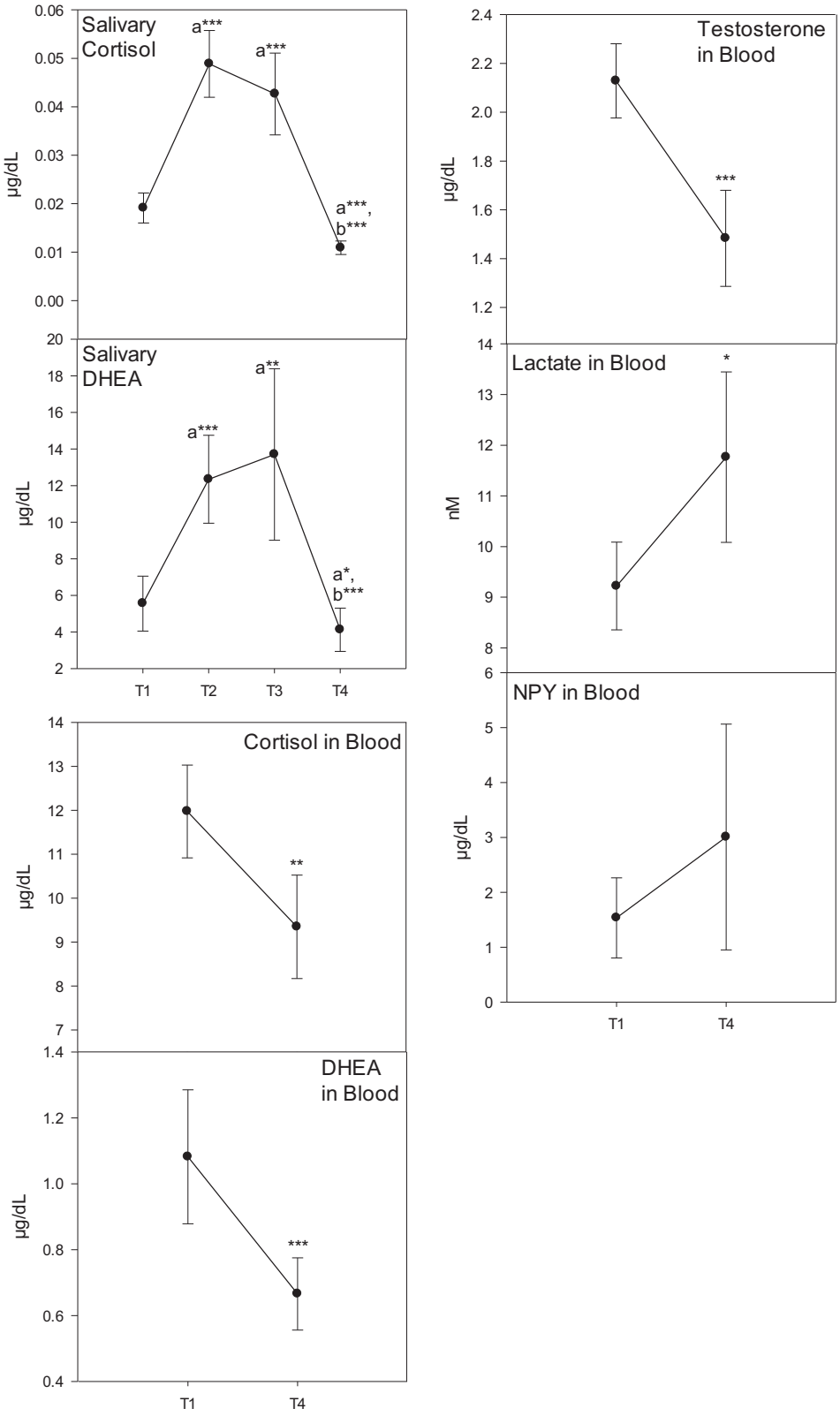

Fig. 3. Effect of CAC training on Saliva & Blood Markers.Notes: [a] = significant difference from T1; [b] = significant difference from T3; Significance levels: (*) = $p \leq 0.05$, (**) = $p \leq 0.01$, (***) = $p \leq 0.001$. For salivary cortisol and DHEA, T1 values represent the arithmetic average of the three measurements taken on Day 1. Error bars indicate 95% confidence intervals.

criteria as a traumatic event. To assess whether endorsing any of those two BTQ items interacted with the outcome measures of interest across time points T1 to T4, we entered each item separately as a between-subjects variable (two levels of endorsement: Yes vs. No) into the analyses of interest involving the following measures: (a) CADSS, (b) salivary cortisol, (c) salivary DHEA, (d) blood lactate, (e) blood cortisol, (f) blood DHEA, (g) blood NPY, and (h) blood testosterone. The results demonstrated that history of trauma did not interact with any of the

aforementioned outcome measures.

4. Discussion

The objective of this study was to quantify the effects of CAC training on psychological function and stress hormone levels. As predicted, compared to baseline, CAC training was associated with adverse changes on all POMS and MFI subscales, as well as scores on CADSS and PSS (re-experiencing and arousal subscales). Scores on all measures returned to baseline or near baseline levels at Recovery/Debriefing. This pattern of change suggests that the psychological perturbations associated with CAC training are transient, and normal psychological function returns shortly after completion of training (i.e., 2–4 h). Furthermore, this study demonstrated that 3 sub-scales of the POMS–confusion/bewilderment, depression/rejection and vigor/activity–assessed prior to the commencement of CAC training predicted successful completion of training. We are not aware of any previous study of military training where the positive mood state of trainees immediately preceding training predicted subsequent success. Given the simplicity of assessing mood, the well-demonstrated ability to rapidly improve it, and its beneficial effects on problem solving, this finding may have some important practical implications for increasing the success rate of various types of training (Ashby et al., 1999.).

As predicted, we also observed a curvilinear relationship between the four measurement time points and salivary cortisol and DHEA levels. These results are generally consistent with the findings obtained from SERE schools in the U.S., and suggest the observed elevations in salivary markers of stress associated with exposure to CAC training are also transient, returning to baseline or near baseline levels at Recovery/Debriefing (Morgan et al., 2000a; Morgan et al., 2001a; Lieberman et al., 2015; Lieberman et al., 2016; Taylor et al., 2007). The hormonal findings from the assays of salivary cortisol and DHEA levels are consistent with the changes in mood, fatigue, dissociation and PTSD symptoms observed and demonstrate CAC training induces acute stress.

Several SERE studies conducted in the U.S. have demonstrated that acute stress-induced by captivity survival training can impair episodic, short-term and working memory, as well as visuospatial and problem solving abilities (Lieberman et al., 2005a; Morgan et al., 2006; Lieberman et al., 2016). In fact, impairments in short-term and working memory as a function of captivity survival training have been observed using the same measures that were employed in the present study (i.e., n-back and dMTS) (Lieberman et al., 2016), exhibiting their sensitivity to stress in this context. However, our measures of cognitive function did not exhibit the predicted relationship between phases of CAC training and performance. Specifically, our results indicated that CAC training had no effect on short-term memory as measured by the dMTS across the four time points. This pattern is not consistent with results of several SERE studies in the U.S (Morgan et al., 2006; Lieberman et al., 2016; Lieberman et al., 2005b). However, there are some differences between training conducted at U.S. SERE schools and Canadian CAC training that could account for the observed inconsistency in findings across studies. In the U.S., each phase of SERE school is substantially longer than CAC and could, therefore, produce different stress levels. Typically, an initial week-long survival phase of SERE school precedes capture and trainees are significantly sleep and food deprived during that phase of training. The captive phase of U.S. SERE school also lasts longer than CAC and could include environmental stressors not present in CAC. Furthermore, both saliva and serum peak cortisol levels measured at CAC were substantially lower than levels at U.S. Army and Navy SERE schools, which could reflect differences in the timing of measurements, in the degree of stress experienced by trainees or in the cumulative impact of stress over the course of training (Morgan et al., 2000a; Lieberman et al., 2016).

In terms of WM, 2-back performance remained stable across interrogations. This is consistent with previous observations that depending on context, stress can both impair and enhance learning and memory (Joëls et al., 2006; Schwabe et al., 2012). One possible explanation for stable 2-back performance could be in terms of compensatory mechanisms. Specifically, elevated signals in the prefrontal cortex (PFC) have been observed in response to exposure to an acute stressor while performing a WM task (Porcelli et al., 2008), suggesting that "stress-related PFC activation increases reflect operations in the service of maintaining organized behavior during stress. Behavioral research highlights the role of PFC in resistance to interference or distraction via executive processes fundamental to WM capacity." In other words, in the presence of acute stress PFC might exert top-down control over behavior, reflected by preserved or improved performance. From a training perspective, our results suggest that inducing stress in trainees could in some cases be beneficial to cognitive function, to the extent that it might mobilize top-down strategies for mitigating its effects.

Aside from measures collected at four time points to assess the effects of CAC training on psychological functions and stress hormone levels, we also collected blood at baseline and at Recovery/Debriefing. Compared to baseline, lactate levels were higher in the Recovery/Debriefing Phase as would be expected as it takes some time for it to recover from severe stress. This observation is consistent with lactate's role as a biomarker of stress (Garcia-Alvarez et al., 2013). Contrary to our predictions, cortisol and DHEA levels were lower in the Recovery/Debriefing Phase. We believe that this pattern highlights the importance of collecting multiple blood biomarkers for a more complete characterization of the effects of stress on hormone levels. Specifically, greater blood cortisol and DHEA levels at baseline compared to Recovery/Debriefing could be reflective of anticipatory anxiety prior to the start of training. Consistent with this interpretation, direct pairwise comparison involving salivary cortisol at baseline and at Recovery/Debriefing demonstrated that the level was higher in the former time point. In addition, reduced testosterone following training could reflect the effect of training-related stress as a reduction in the level of testosterone is a marker of HPA activity (Lieberman et al., 2005b) and has been observed under a variety of stressful conditions including military training (Opstad, 1994), exposure to chronic military stress (Friedl et al., 2000), and captivity survival training (Morgan et al., 2000a; Lieberman et al., 2016). In this sense, the pattern observed here is consistent with the HPA activity typically induced by CAC training.

There was no change in NPY level between baseline and Recovery/Debriefing. There is evidence from U.S. SERE school studies to suggest that the NPY response may buffer against the impact of stress on performance (Morgan et al., 2000a,b). Consequently, it might be expected that a difference between course completers and non-completers in NPY levels would be observed (Morgan et al., 2001a), but this was not seen in the present study. This may simply have been an artifact of the unequal group sizes of completers and non-completers in the present study, or due to the degree of stress experienced by participants. It also may reflect the less sustained nature of the stress of CAC training vs. SERE school. Regardless, further investigation of compensatory mechanisms activated during CAC training is warranted.

Finally, and contrary to expectation (Morgan et al., 2006; Morgan et al., 2001b; Dimoulas et al., 2007) prior history of trauma did not predict stress reactivity during captivity survival training. There might be at least three reasons for this observation. First, the stress induced during training might not have been sufficiently high to differentially impact stress reactivity among those participants with a history of trauma. Second, given our relatively small sample size, our analyses were likely underpowered for examining group differences involving those with and without history of trauma. Finally, our sample might have been biased by being composed of particularly well-adapted individuals, who in turn exhibited low reactivity to stress despite a history of trauma. Of course these possibilities are not mutually exclusive, and can be examined in future studies.

5. Limitations

Our study had several limitations that should be taken into consideration when evaluating the results. If a larger number of volunteers were recruited, more robust effects of CAC training may have been observed. Furthermore, the sample consisted primarily of males. Although the gender distribution observed here represents what is typically observed in CAC training, caution must be exercised in drawing inferences and making generalizations to both genders based on the present results. Also, logistical and analytic considerations placed constraints on the number of measures collected and biomarkers analyzed. For example, inclusion of additional tests of cognitive performance may have revealed cognitive impairments in functions not examined in this study. Also, although our salivary measures demonstrated the predicted curvilinear relationship between CAC training and stress, cortisol and DHEA do not represent the full spectrum of the body's response to stress. The human response to stress involves the sympathetic nervous system (SNS) and the hypothalamus-pituitary-adrenal (HPA) axis (Joëls et al., 2006; Schwabe et al., 2012), so measures of the SNS, such as epinephrine, would have been useful. Because cortisol and DHEA are both regulated by the HPA axis, stress in relation to CAC training as measured by salivary samples might have exhibited a different profile had we included other biomarkers of stress at the four time points. Such additional analyses would augment future studies.

6. Conclusions

As a consequence of exposure to CAC training significant changes in numerous psychological and biological parameters including mood, symptoms and stress hormones were observed. From a training perspective, teaching relevant coping mechanisms for mitigating the effects of combat-related stress on performance is hypothesized to depend on controlled exposure to operationally realistic stressors during training. Although our study was not designed to determine whether the level of stress-induced during training was optimal for stress inoculation and/or skill acquisition, it does demonstrate that extensive but transient elevations in various measures of stress occur during CAC training. Several unexpected and novel findings emerged from our study: First, memory performance was unaffected by training, suggesting that a relatively short duration of intense stress might be insufficient for degrading cognitive performance. Second, mood assessed prior to training predicted successful completion of training, which bears an important practical implication for increasing the success rate of training in similar training environments. Third, prior history of trauma did not predict stress reactivity during training, suggesting the need for further research to examine training and population characteristics that might moderate stress reactivity in this context. The results of this study form the basis for examining the relationship between stress, skill acquisition, and forward transfer of learning in future CAC studies. Further research on stress inoculation in humans could re-expose soldiers to stress and assess the impact of previous CAC or SERE training.

Conflicts of interest and source of funding

The authors declare no conflict of interest. Funding for this study was provided by a Department of National Defence Agility Fund under the direction of BC, and an Applied Research Project under the direction of OV.

Acknowledgments

We thank the students and instructional staff for making this study possible. We acknowledge the contributions of LCol Gary Ivey (Director General Military Personnel Research and Analysis, DGMPRA) to study design and data collection, individuals from the University of Toronto's Centre for Biological Timing and Cognition (Suzanne Ackloo, Ken Seergobin and Crystal Dykstra) for data analysis, as well as the following DRDC personnel to data collection and analysis (listed in alphabetical order): Fethi Bouak, Brenda Fraser, Andrea Hawton, Tonya Hendriks, Kevin Hofer, Quan Lam, Henry Peng, Christina Powlesland, Doug Saunders, Ingrid Smith and Wendy Sullivan-Kwantes. We also thank Marques Wilson from USARIEM for generating the figures.

The views, opinions, and findings in this report are those of the authors and should not be construed as an official U.S. Department of Defense or Army position, policy, or decision, unless so designated by other official documentation. Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations. The investigators have adhered to the policies for protection of human subjects as prescribed in DOD Instruction 3216.02 and the research was conducted in adherence with the provisions of 32 CFR Part 219.

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Cindy Suurd Ralph, Oshin Vartanian, Harris R. Lieberman, Charles A. Morgan III, Bob Cheung

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
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In the Canadian Armed Forces (CAF), Conduct After Capture (CAC) training is a 4-day captivity survival course during which soldiers are exposed to increasing stress, and evaluated on their ability to accomplish military objectives. We hypothesized that: (a) compared to baseline, CAC training would cause signif cant, reversible perturbations in measures of psychological functioning and serum and salivary stress hormone levels relevant to models of stress hardiness and vulnerability; and (b) deviations from baseline would be maximal at the time point of most intense stress during training. CAF personnel were assessed at baseline, twice during training (immediately prior to a less challenging interrogation role-play scenario and again following another much more intense interrogation role-play scenario), and after completion of training. At each occasion, mood, fatigue, dissociation, PTSD symptoms, short-term and working memory, and salivary cortisol and dehydroepiandroster-one (DHEA) were assessed. As predicted, scores on all measures were degraded during CAC but recovered after completion of training, and almost all measures were most degraded at the more intense interrogation role-play scenario. Unexpectedly, memory performance was unaffected by training, suggesting that a short duration of intense stress might be insufficient for degrading it. Another unexpected f nding was that mood assessed prior to training predicted successful completion of training, which bears important practical implications for increasing the success rate of training in similar environments. These results demonstrate that despite its relative brevity, CAC training nevertheless induces signif cant but reversible effects on psychological and physiological function—necessary preconditions for stress inoculation training.

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Military; Cortisol; Dissociation; Fatigue; Anxiety; Working memory